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The evolution of Roman urban environments through the archaeobotanical remains in Modena – Northern Italy

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A B S T R A C T

The paper reports on the urban archaeobotany of Modena, a town that lies on the southern Po Plain of the Emilia Romagna region, Northern Italy. Founded in 183 BC, it was an important Roman colony known as *Mutina*. The integrated study of micro- and macro-remains, the interdisciplinary archaeological and botanical approach, and the comparison of on-site/off-site records allow the reconstruction of an urban environment of the past. Pollen and macroremains from four archaeological sites located in and around the ancient walls, along with pollen from an off-site trench, were studied with an integrated approach, aimed at reconstructing the main floristic, vegetational and palaeoecological features of the town and its surroundings between the 6th century BC and the 10th century AD. During the Roman age, the natural plant landscape was characterised by wetlands, thinly scattered mixed oak woods, cereal fields, gardens and other human environments; during the Late Roman and Early Medieval age, the woodlands increased. Some currently rare, or locally extinct, species lived in the area. The fragmentation of the landscape has been evident since the Roman times because pieces of the natural environments have survived near lands strongly modified by inhabitants.

1. Introduction

Urban archaeobotany investigates plant remains from complex anthropogenic contexts, discovered against the background of the historic centres of modern cities (Greig, 1996; Mercuri et al., 2014a). In a broader sense, it investigates the history of past towns (e.g. Murphy et al., 2013). This type of research provides original results, especially when layers with plant records have been deposited over a long time period and in various contexts. The local histories of food and trade, and the environments where settlements developed from the Medieval to Renaissance ages, have been obtained from research on the cities of North–Central Europe (Beneš et al., 2002, 2012; Karg, 2007; Święta-Musznicka et al., 2013). In the Western Mediterranean, agriculture and plant uses from the Roman age to the Islamic period (2nd BC to 11th century AD) have been investigated from the excavations in Lleida, Catalonia (Spain; Alonso Martinez, 2005).

In Italy, a complex framework of gardens, cultivations and plant landscapes from layers found in urban contexts have been studied in important cities such as Rome (Coletti et al., 2006; Sadori et al., 2010a, 2011), Florence (Mariotti Lippi et al., 2013) and Ferrara. In the latter, located in eastern Emilia Romagna, the archaeological excavations of nine sites have brought impressive amounts of well-preserved plant remains to light. Pit and channel deposits have been studied in order to reconstruct the development of this city over the Medieval and Renaissance ages (13th–15th century AD; Bandini Mazzanti et al., 2005). Traces of luxury food found in rubbish pits confirmed the high social status of the ruling dukes (Este family; Bosi et al., 2009). In the same region, a significant land transformation occurred in the area which is currently the historical centre of Parma; the vegetal waste and parasite remains found in rubbish pits show that the site was a sacred area during the Roman age and a market during the Medieval ages (Bosi et al., 2011a; Florenzano et al., 2012). All this research demonstrates that the environmental development of urban areas unquestionably depends on the cultural history of people who have transformed them over time (Bosi et al., 2011b; Rinaldi et al., 2013).

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This paper investigates the palaeoenvironmental transformations of Modena, an important urban centre of Emilia Romagna, and adds direct original information on the activity that Romans carried out in the Mediterranean area. Though the Romans had assigned these northern lands to veterans and the rural classes since the 3rd century BC, the Roman town *Mutina* was founded in 183 BC for defence, linked to campaigns in the Cisalpine Gaul (Malnati, 1988; David, 2002; Calzolari, 2008). Mentioned by Cicero as a solid and prosperous colony, it was a strategic military and economic centre. In recent years, a new law has protected the archaeological heritage of the town, and archaeological sites have been more and more subjected to rescue archaeology. Thanks to the cooperation with the Superintendence of Archaeological Heritage of the region, many sites dating to the Roman period have been investigated. The integrated analyses of microscopic and macroscopic plant remains (pollen, seeds and fruits, charcoal/wood) have provided specific palaeofloristic data and palaeoethnobotanical information (e.g. Bandini Mazzanti et al., 2001; Rinaldi, 2010; Bosi et al., 2014).

The aim of this paper is to follow the land transformations that occurred in the wake of the town's foundation, as well as the environmental changes and plant diversity that characterised Modena in Roman times. For this reason, five sites with very different contexts in the past were selected within the borders of the modern town. Their study allows an on-site/off-site comparison. Data from various sets of micro- and macro-botanical records were deeply integrated to obtain the environmental reconstructions. Notes on the Medieval landscape observed in three sites are also reported for comparing land-use transformations.

2. Materials and methods

Modena (44°38′ N–10°55′ E; 34 m asl) is a town in Emilia Romagna – Northern Italy (Fig. 1a). It lies on the Po Plain, the flat land above the northern slopes of the Tusco-Emilian Apennines. The rivers Secchia and Panaro mark the borders of its territory to the West and East, respectively. The region is part of the high-rainfall Mediterranean-climate areas with sub-continental climate (Sander and Wardell-Johnson, 2012). Some characteristics of continental climate are especially present in the inner part of the plain with strong variations in temperature between summer and winter, scarce atmospheric circulation and fog. The mean annual rainfall is 650–800 mm, and the annual temperature range from approximately −20 °C to 35 °C (ARPA in Danin et al., 2014).

The geomorphological landscape is characterised by alluvial fans, fluvial ridges, palaeo-riverbeds, natural springs, and by forms connected to human activities present at least since the Neolithic and Bronze ages (Mercuri et al., 2006; Castaldini et al., 2007). The catchment area of the alluvial plain lowlands includes the Apennine lower mountain and hill belts. Flooding events closing the underlying stratigraphies characterised the Roman period, in particular as continuous phenomena between 0 and 600 cal yr AD (Cremonini et al., 2013).

Vegetation is distributed in four altitudinal belts: a) the plain (0–100 m asl), with cities and fields, and a high level of human disturbance; b) hills (100–900 m asl), where woods of broadleaved *Quercus* and *Ostrya carpinifolia* reach the highest limit; c) mountains (900–1600 m asl), with *Fagus sylvatica* woods; d) the suprasylvatic belt with grasslands and *Vaccinium* moors (Alessandrini et al., 2010).

2.1. The archaeological context and the sites investigated in Mutina

Modena is rich in archaeological sites, especially from the Roman Republican (3rd BC–1st century AD), Imperial (1st–3rd century AD) and Late Roman phases (4th–first half of the 6th century AD). Between 2009 and 2011, excavations brought to light also archaeological layers dating to phases from the Iron age (6th–5th century BC) to the Late Medieval age (second half 6th–10th century AD).

The data set analysed includes pollen and seed/fruit samples taken from four archaeological sites (on-site), and pollen samples taken from one off-site trench (Fig. 1b,c).

The sites investigated were selected by considering the following factors: a) the archaeological sites, discovered in the underground during building and road works, were located within the perimeter of the modern town of Modena (Fig. 1b); b) the layers were deposited prevalently during the Roman phases; c) the contexts of the archaeological sites were originally very different, located inside, close to or outside of the centre of the old town; they were stratigraphically excavated, and studied for pollen and macroremains; d) the off-site trench was actually located outside the Roman town, and includes layers that were deposited when the archaeological sites developed.

The sites belong to five sectors of Modena (Fig. 1c,d): the centre of the Roman town *Mutina* (MO-arch2), the immediate outskirts (MO-arch1, MO-arch4), and areas located to the South (MO-arch3) and East (University Campus, Trench *Campi-S2*) of the Roman town. The layers datable to the Roman age lie at about 5 m below the ground level, and are covered by the Early Medieval layers. Archaeological layers consist of floors or rooms/buildings while paleosols and alluvial layers, originating from floods, are prevalently stratified outside the ancient town (Fig. 2). Waterlogged conditions preserved deposits rich of well-preserved organic material.

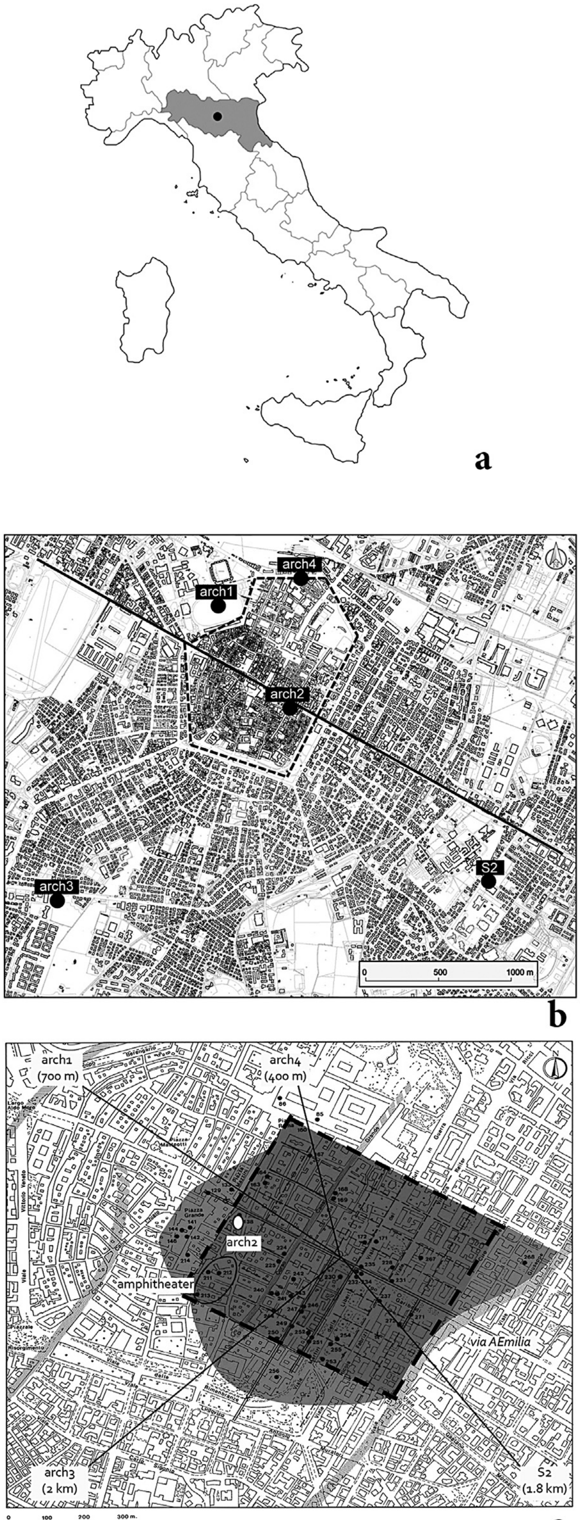
The chronology of the archaeological and alluvial layers is based on findings (mainly coins and pottery), stratigraphical correlations and radiocarbon datings (Lugli et al., 2002; Cremonini et al., 2013; Labate, 2013). The chronology of the Trench is based on archaeological finds, stratigraphical correlations, and radiocarbon datings obtained from wood (CEntro di DAtazione e Diagnostica - Università del Salento, Lecce). In the site MO-arch3, dendrochronological analyses were carried out fifty samples: pieces of trunks of deciduous oaks and elms, that were preserved waterlogged, dated to the Roman period and with more than forty tree rings were selected (DENDRODATA: Martinelli and Pignatelli, 2013). Calibration was performed using OxCal 4.1.7 (Bronk Ramsey, 2005).

2.2. The four archaeological sites

Based on the chronology, the archaeological contexts are described below, from the site with the earliest layers (c. 6th century BC) to that with the most recent layers (c. 10th century AD) (Table 1).

2.2.1. MO-arch1: Novi Sad (6th BC–6th century AD)

This suburban area of *Mutina* was located about 700 m North-East from the Roman town, and was discovered during the construction of an underground car park situated in the centre of the modern town (Labate et al., 2010). Archaeological investigations have brought to light deposits rich of organic remains, landfills and a basin that has been filled by mixed deposits over several years, from the Iron to Modern ages. The deposits became stratified layers; their origin was due to both human activities and alluvial deposits. At the bottom of the stratigraphy, 7 m deep, a soil dated to the 6th–5th century BC was covered by an alluvial layer; then,



Site label	Site name	seeds/fruits: archaeological context	layer	nr. of samples	chronology	litres	pollen: archaeological context	layer	nr. of samples	chronology	mean pollen counts per sample
MO - arch 4	EX MANIFATTURA TABACCHI						flood	182	2	5th - 6th AD	382
		flood	147	1	340 - 550 AD*	*27*	flood	147	2	340 - 550 AD*	
							soil	148	3	4th - 5th AD	
		soil	155	1	1st - 2nd AD	*13*	soil	155	1	1st - 2nd AD	
MO - arch 3	VIALE AMENDOLA (EX POLIZIA MUNICIPALE)	phase B - woodland					phase B - woodland	4	3	*post* 6th - Early Middle Age	486
								37	1	5th - 6th AD	
		phase B - woodland: woodland, alluvial deposit	6, 5	2	455-537 AD°	*18*		6, 5	4	455-537 AD°	
			7	1	4th - 5th AD	*10*		7	4	4th - 5th AD	
		phase A - Roman aqueduct					phase A - Roman aqueduct: water drainage system	18	1	1st - 2nd AD	
		phase A - Roman aqueduct: filling channel aqueduct	10	1	1st - 2nd AD	*6*					
		filling settling tank	33	1		*8*					
		filling bottom settling tank	38	1	1st AD	*3*					
		layer above settling tank	35	1	*ante* 1st AD	*6*					
							phase A - Roman aqueduct: soil	15	2	2nd BC - 2nd AD	
MO - arch 2	EX CINEMA CAPITOL	*post-domus* (abandonment and spoliation)	39, 17, cut 1	3	2nd - 3rd AD	*33*					605
		Imperial *domus*	2, 26, cut 2	3	1st - 2nd AD	*152*	Imperial *domus*	2	1	1st - 2nd AD	
		Republican *domus*	21, 22, 24, 46, 28, cut 3	6	2nd - 1st BC	*147*	Republican *domus*	21, 22, 24, 46	4	2nd - 1st BC	
		pre-domus (layers very anthropized)	12, 57, 54	3	3rd - 2nd BC	*187*	*pre-domus* (filling hole)	13	1	3rd - 2nd BC	
MO - arch 1	NOVI SAD						*post*-woodland	60	1	*post* 5th - 6th AD	474
							flood *pre*-woodland	7	1	390 - 590 AD*	
							pre-woodland	8, 61	2	*post* 5th AD	
							flood *pre*-late Roman settlement	10, 1557	2	3rd - 5th AD	
		landfill (within the basin)	3132	1	1st - 2nd AD	*3*					
			1578	1		*38*					
		deposit of basin	1572, 1559, 1561, 1560	4	1st AD	*36*	deposit of basin	1559, 1561	2	1st AD	
			1577	1	1st BC - 1st AD	*8*					
							soil	1569	1	6th - 5th BC	

d

Fig. 1. (a) – Location map of Modena in Emilia Romagna region, Northern Italy, and (b) the five sites studied in this paper; the dotted line marks the borders of the historic centre of the modern town; the black line marks *Via Aemilia*, the Roman street that crosses the town. (c) Border limits of *Mutina* have changed in the different phases of the Roman period: the central square is *Mutina* during the Republican phase, while the expansion wings sign the limits of the town during the Imperial phase. During the Late Antique phase, the town boundaries did not change but the green and rural areas were contracted. (d) Layers and archaeological contexts of the four archaeological sites (MO-arch) (* = radiocarbon date; ° = dendrochronology and radiocarbon date).

Roman layers with a street, a necropolis, rustic houses, waste deposits and a discharge area were found 6 m down, dating to the 3rd century BC to the 3rd AD. A second alluvial layer was found at c. 5.7 m depth, dating to the 3rd–4th century AD, with the re-use of the street, necropolis and houses. A third alluvial layer at c. 4.7 m depth seals the Roman layers. A monastery (at 2.2 m depth; 13th–14th century AD) and a plague cemetery (17th century AD)

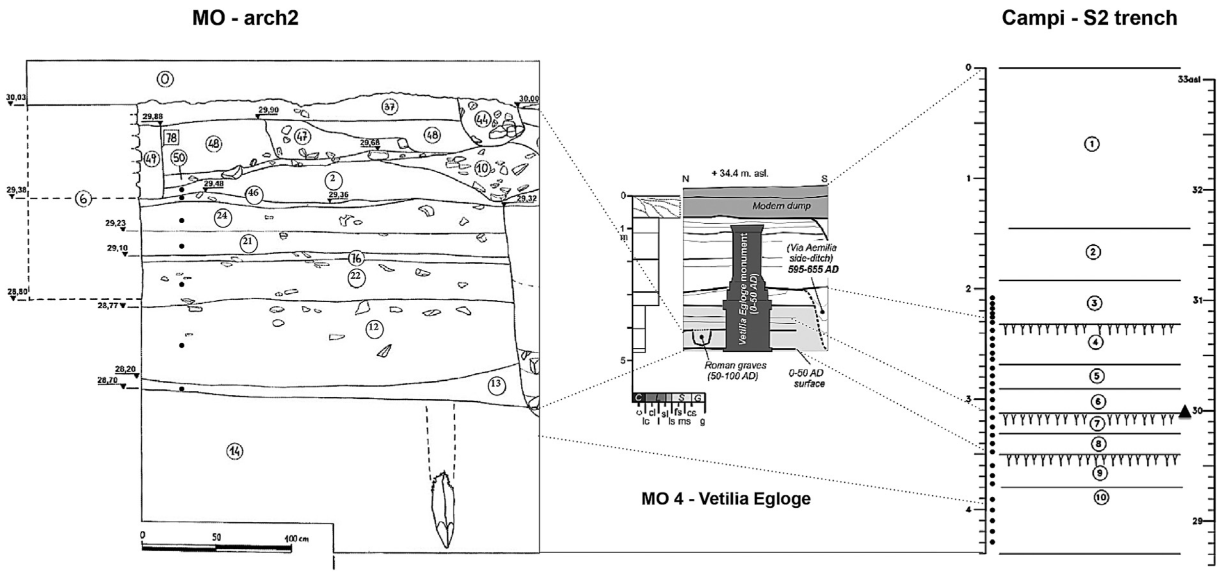


Fig. 2. Stratigraphy and pollen sampling of MO-arch2 and Trench Via Campi-S2, correlated with the site MO4 – Vetilia Egloge discussed in Cremonini et al. (2013, modified). ♦palaeosol; σ radiocarbon dates on wood; λ pollen sample.

constitute the highest levels of this stratigraphy. Today this is an open park located at the centre of the town.

2.2.2. *MO-arch2: area ex-cinema capitol (3rd BC–3rd century AD)*

A rich Roman *domus* was discovered during construction works below ground level in the historical centre of the town. Archaeological deposits from the Roman age, lying on top of

Table 1
Chronology and number of samples from the archaeological sites (dotted patterns mark periods partially covered by the samples).

Sites / Chronology	MO-arch1					MO-arch2					MO-arch3					MO-arch4				
	NOVI SAD					EX CINEMA CAPITOL					VIALE AMENDOLA					EX MANIFATTURA TABACCHI				
seeds/fruits	7 samples					15 samples					7 samples					2 samples				
pollen	10 samples					6 samples					15 samples					8 samples				
Early Middle Age																				
8 AD											3									
7 AD				1																
6 AD			2									2		5					2	
5 AD	2	1									1		4			1	3	2		
4 AD																				
3 AD									3											
2 AD			2					3		1	1		2			1	1			
1 AD	1	4		2								1		2						
1 BC							6		4		1									
2 BC						3		1												
3 BC																				
4 BC	1																			
5 BC																				

alluvial layers, were found at a depth of around 7–3 m. Several coins and a great quantity of ceramic items made it possible to attribute the layers of the *domus* to different chronological phases (Benassi and Guandalini, 2011). The *domus* was built over layers dating to the early phases of Romanisation in the Republican age (3rd–2nd century BC), renovated in the early Imperial age (1st–2nd century AD), and then abandoned around the 2nd–3rd century AD.

2.2.3. MO-arch3: Viale Amendola (2nd BC–9th/10th century AD)

Modern building works brought to light soil from the Roman age buried at c. 3.4 m from the surface, located about 2 km South-West of *Mutina* (Anghinetti et al., 2011). A drainage channel and an aqueduct with a settling tank, dating to the 1st century AD, were covered by an alluvial layer at 3.1 m. The layer was then colonised by a woodland, as shown by the presence of large trunks that had fallen, found near stumps. Oaks and elms were identified, and the trunks more than 122 years old were subjected to dendrochronological analyses (see above). Two radiocarbon datings performed on one trunk gave a dating of 319–539 AD (87.1%) and 327–543 AD (92.9%). These data made it possible to establish that the youngest tree rings formed at c. 455–537 AD (Martinelli and Pignatelli, 2013).

2.2.4. MO-arch4: Ex-Manifattura Tabacchi (1st–10th century AD)

The urban redevelopment plan included works below the ground level that shed light on a Roman paleosol buried at c. 5 m, about 400 m North-West of *Mutina*. One alluvial layer at c. 3.6 m covered the paleosol, and included archaeological findings, plant and wood remains. One piece of wood was dated to 340–550 AD (95.4%, 2σ; 1619 ± 40 uncal years BP – LTL13089A). Post-Roman alluvial layers closed the stratigraphy at c. 2.7 m of depth.

2.3. The off-site trench

The *Campi-S2* Trench was cut in the foundations during the construction of a new building at the University Campus, about 1.8 Km South-West of the historical centre. The stratigraphic series, about 4 m thick, consists of paleosols and alluvial layers of the Roman and post-Roman ages (Labate, 2013; Librenti, 2013). Ten layers (Stratigraphical Units = SU) were identified including two Roman paleosols (Fig. 2).

A paleosurface at the top of the SU 4 (2.3–2.7 m) with bioturbation by human activity correlates with the layer found at 3.1 m at MO4-Vetilia Egloge (this site is about 800 m far from the trench) dated to 595–655 AD (i.e. the Early Medieval age; Cremonini et al., 2013). The paleosol in SU 7 (3.1–3.3 m), with many trunks, wood pieces, and brick fragments (4th–5th AD, Late Roman) was radiocarbon dated: (i) 310–540 AD (85.0%, 2σ; 1657 ± 45 uncal years BP – LTL 12486A); (ii) 330–540 AD (95.4%, 2σ; 1639 ± 35 uncal years BP – LTL 12487A).

2.4. Pollen analysis

In the archaeological sites, pollen samples were taken from exposed trenches and layers according to the archaeological stratigraphy (Fig. 1d).

In the *Campi-S2* Trench, pollen samples were collected from the exposed profile at c. 10 cm intervals, taking the stratigraphy into account and avoiding the reworked SU1. The 30 samples collected from the bottom to ca. 2.0 m are presented in this paper as they correspond to the Roman period during which the main phases of the archaeological sites had developed, and to the subsequent Early Medieval phase (Fig. 2).

Pollen samples, of about 8 g each, were prepared using tetra-Na-pyrophosphate, HCl 10%, acetolysis, separation with NaMetatungstate hydrate, HF 40%, and ethanol (see Florenzano et al., 2012). *Lycopodium* tablets were added to calculate concentrations (pollen/gram). Pollen slides were mounted on glycerol jelly. Identification was made at 1000× magnification, with the help of the reference pollen collection, keys and atlases (e.g. Moore et al., 1991; Reille, 1992). The identification of Cerealia type pollen – including *Hordeum* group and *Avena/Triticum* group – is mainly based on Beug (1964), and on Faegri and Iversen (1989), with a correction factor for glycerol jelly). Non-pollen palynomorphs were identified according to Grenfell (1995) and van Geel et al. (2003). The pollen sum – PS includes all pollen grains. The percentages of Reworked pollen (RW) are calculated on the PS + RW sum, and Non Pollen Palynomorphs (NPPs) on the PS + NPPs sum. Diagrams were drawn with TGView (Grimm, 2004); taxa grouped in main sums are reported in Tables 2 and 3.

2.5. Seed and fruit analysis

A systematic sampling of macroremains during the excavations was planned with the archaeologists. Sediment samples, from 3 to 134 l each depending on the different contexts studied, were floated and water-sieved through a three-sieve bank of 10, 0.5 and 0.2 mm. Seeds and fruits (sf) from each fraction were sorted and counted under a Wild M10 stereomicroscope. The identification was made at 80× magnification with the reference collection, atlases and keys (e.g. Berggren, 1969, 1981; Cappers et al., 2006).

3. Results

The state of preservation of pollen and macroremains was generally good/very good. Pollen preservation was decidedly better in the samples from the archaeological sites than in those from the trench. Plant macroremains were waterlogged, and only a few of them were found charred (in MO-arch1 and MO-arch2; ESM Table).

In the archaeological sites, a mean of 480 pollen grains per sample was counted in 38 samples. Pollen concentration is c. 64,000 p/g on average, ranging from 4400 p/g (min. in MO-arch1)

Table 2
Pollen taxa included in the sums presented in pollen diagrams (Figs. 3 and 5 of the text). Plant habitus and ecology are according to Pignatti (1982).

Sum	Pollen taxa
Oak wood	*Acer campestre* type, *Carpinus*, *Corylus*, *Fraxinus*, *Ostrya carpinifolia/Carpinus orientalis* type, broadleaved *Quercus*, *Tilia*, *Ulmus*
Wetlands	**Hygrophilous trees**: *Alnus*, *Populus*, *Salix* **Hygrophilous herbs**: *Cicendia filiformis*, Cyperaceae, *Lythrum*, *Typha/Sparganium*, *Typha latifolia* type **Hydrophytes** (Pignatti, 1982): *Alisma* type, *Butomus*, *Callitriche*, *Ceratophyllum*, *Hydrocharis*, *Lemna*, *Myriophyllum*, *Nuphar*, *Nymphaea alba* type, *Potamogeton*, *Ranunculus aquatilis* group
Ornamental plants	*Buxus*, *Celtis*, *Myrtus*, *Taxus*; *Acanthus*
Other cultivated plants	*Castanea*, *Juglans*, *Morus*, *Olea*, *Vitis*; *Anethum graveolens*, *Cannabis*, cereals (*Avena/Triticum* group, *Hordeum* group, *Panicum*, *Secale*), *Cuminum cyminum*, *Vicia faba*
Synanthropic plants	*Sambucus nigra*; *Adonis annua* type, *Anagallis arvensis* type, *Artemisia*, *Centaurea nigra* type, *Convolvulus arvensis*, *Fumaria* cf. *capreolata*, *Galium* type, *Mercurialis*, *Orlaya grandiflora*, *Papaver rhoeas* type, *Plantago*, *Polygonum aviculare* type, *Rumex*, *Torilis nodosa* type, *Urtica*, *Verbena officinalis*

Table 3
Synthesised results of seed/fruit analyses: number of records counted in each context (top) and in each archaeological site (bottom); (*s.l.* = *sensu lato*;* = radiocarbon date; ° = dendrochronology and radiocarbon date).

Site	MO – arch 1				MO – arch 2				MO – arch 3					MO – arch 4	
									Phase A – Roman aqueduct				phase B – woodland		
Archaeological context	Wetland basin		Landfill (within the basin)		Pre-*domus* (layers very anthropized)	Republican *domus*	Imperial *domus*	Post-*domus* (abandonment and spoliation)	Layer above settling tank	Filling bottom settling tank	Filling settling tank	Filling channel aqueduct	Woodland, alluvial deposit	Soil	Woodland
Chronology	1st BC–1st AD	1st AD	1st–2nd AD	1st–2nd AD	3rd–2nd BC	2nd–1st BC	1st–2nd AD	2nd–3rd AD	*ante* 1st AD	1st AD	1st–2nd AD		4th–5th AD/ 455-537 cal AD°	1st–2nd AD	340 AD (95.4%)–550 AD*
Total seeds/fruits	1978	18,510	8632	2198	6390	3013	486	395	90	248	4860	4024	7446	203	796
nr. sf/1 l	247	514	227	733	34	20	3	12	15	83	608	671	266	16	29
Cultivated fruit plants	24	39	86	205	919	427	48	53	3	2	40	20	11	3	2
Wild fruit plants	2	70	14	30	57	62	17	3	2	10	32	4	91	65	4
Cereals			1	3	23	43	7	2							
Vegetable and aromatic plants	2	47	11	54	18	13	2	0	1	2	128	66			
Ornamental plants		4		20	2	8	1	0	1		1	1			2
Ruderal plants (weeds *s.l.*)	404	7033	2250	910	2745	921	200	143	5	31	2185	245	24	16	94
Wetland plants	1497	11,129	6118	661	2526	1496	200	193	65	131	1866	3452	7088	101	427
Other plants	49	188	152	315	100	43	11	1	13	72	608	236	232	18	267
Total seeds/fruits SITE	**31,318**				**10,284**				**16,668**					**999**	
nr. sf/1 l site	368				20				327					25	
Cultivated fruit plants	354				1447				76					5	
Wild fruit plants	116				139				139					69	
Cereals	4				75				–					–	
Vegetable and aromatic plants	114				33				197					–	
Ornamental plants	24				11				3					2	
Ruderal plants (weeds *s.l.*)	10,597				4009				2490					110	
Wetland plants	19,405				4415				12,602					528	
Other plants	704				155				1161					285	
NR. TAXA sf SITE	***206***				***177***				***143***					***32***	
Cultivated fruit plants	*9*				*4*				*6*					*1*	
Wild fruit plants	*11*				*6*				*8*					*2*	
Cereals	*3*				*6*				–					–	
Vegetable and aromatic plants	*6*				*8*				*4*					–	
Ornamental plants	*2*				*5*				*1*					*1*	
Ruderal plants (weeds s.l.)	*61*				*71*				*32*					*3*	
Wetland plants	*68*				*50*				*55*					*12*	
Other plants	*46*				*27*				*37*					*13*	

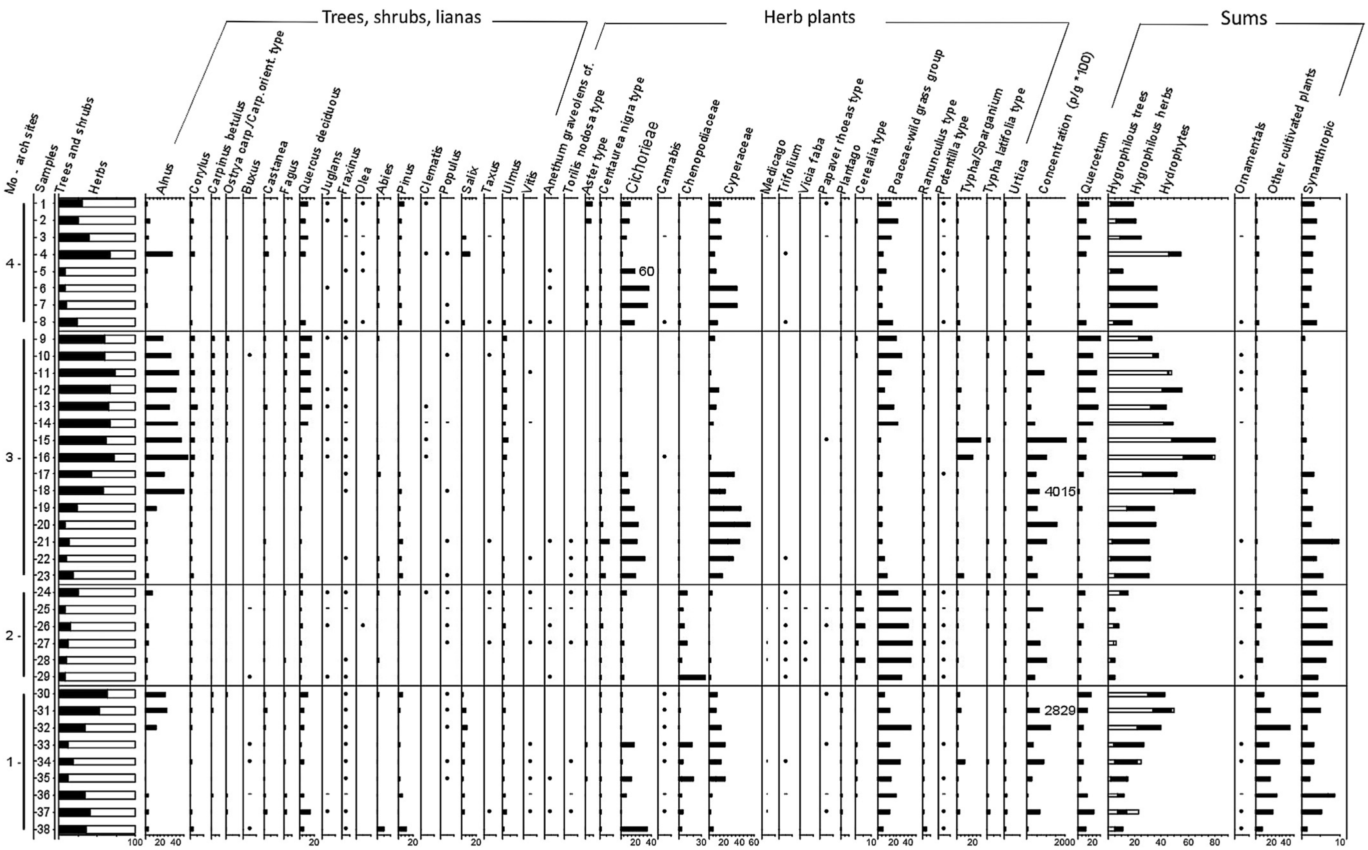


Fig. 3. Percentage pollen diagram of the four archaeological (MO-arch) sites of *Mutina*. Taxa included in the sums are listed in Table 1.

to 402,000 p/g (max. in MO-arch3). Tree/shrub sum is low (34% on average). The prevalent taxon is *Alnus* (15%), and in general spectra are dominated by deciduous *Quercus* (6%) with Poaceae-wild grass group (18%), Cyperaceae (14%) and Cichorieae (11%). Conifers are mainly represented by *Pinus* (3%) and *Abies* (0.6%). Pollen of *Castanea* (0.7%) is fairly common; *Juglans* (0.1%) and Cerealia type (0.9%) are less common but important (Fig. 3).

A total of c. 59,000 seed/fruit records were counted in 31 samples. Macroremains prevalently belong to wetland plants, while cereals and vegetables, cultivated and wild fruit plants, and synanthropic species are distributed variously across the sites (Fig. 4; see the detailed analyses in ESM Table).

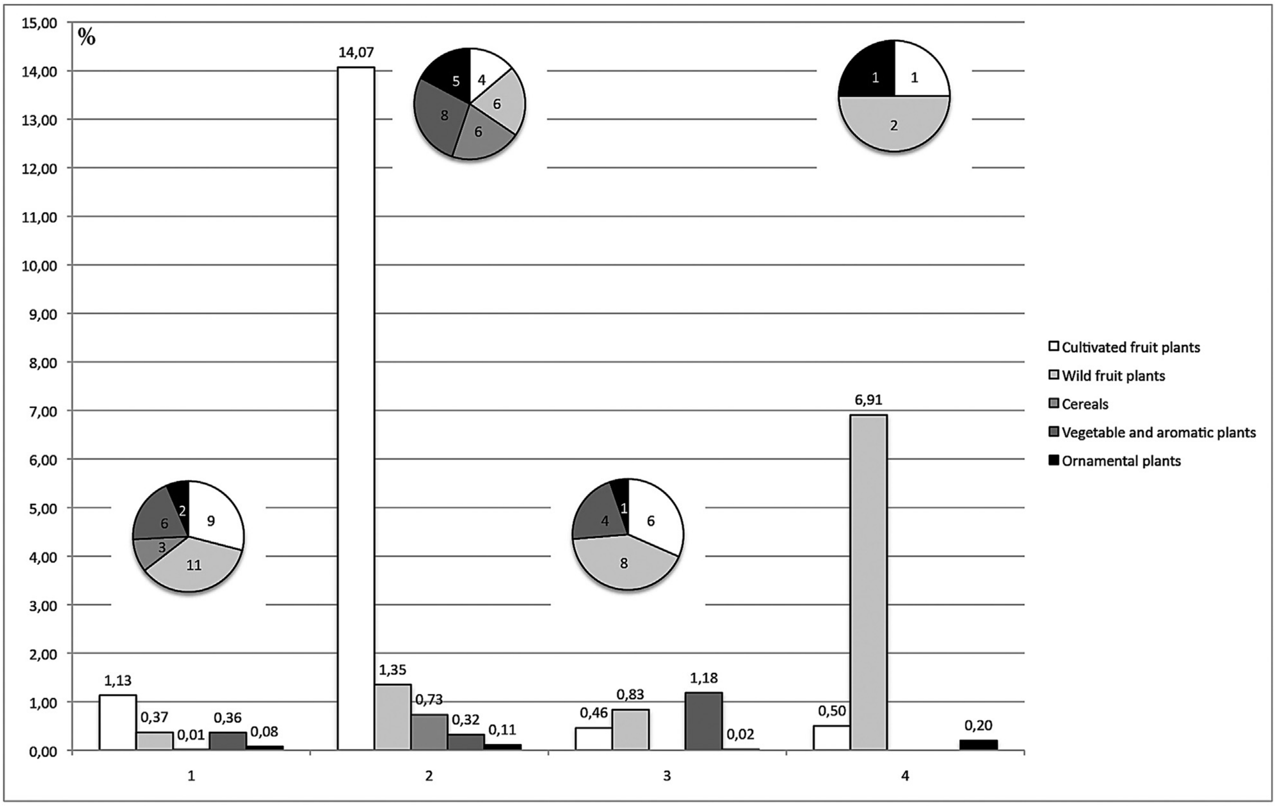
In Trench *Campi-S2*, a mean of 514 pollen grains per sample was counted in 30 samples. The mean concentration is c. 9100 p/g, with higher values in layers from the bottom part. The mean tree/shrub sum is 40% on average, and shows increasing values from the Republican/Imperial (22%), to the Late Roman (43%) and Early Medieval (57%) ages. In the diagram, the prevalent tree taxa are deciduous *Quercus* (12%), *Alnus* and *Pinus* (7% each), *Ulmus* (3%) and *Abies* (2% each). Poaceae-wild grass group (19%) and Cichoriae (14%) prevail among herb taxa (Fig. 5). Significantly, the presence of *Castanea* (0.7%), *Juglans* (0.2%) and Cerealia type (0.6%) is recorded in many samples.

4. Discussion

Although taphonomic problems may affect plant assemblages in archaeological contexts, the archaeobotanical results obtained from the five sites of Modena give a coherent image of open vegetation, wetlands and human environments. This result shows that pollen and seeds/fruits from archaeological sites are basically a result of human transport but a variable component from natural plant cover may be included in layers depending on the context (Sadori et al., 2010b; Święta-Musznicka et al., 2013; Mercuri et al., 2014a).

The sediments of Trench *Campi-S2* were accumulated out of an archaeological site, and therefore the contribution of natural plant cover to the deposit is expected to be higher than that in the archaeological layers. However, the presence of many alluvial layers in the trench suggests that the long distance water transport of pollen may have had an important role in this deposit. Alluvial layers are common part of the deposits of the Po Plain, and were also present in the ancient town (Figs. 1c and 2). In general, alluvial deposits have fairly typical pollen content with low concentration, large amount of reworked (secondary) pollen, and pollen produced by plants living at higher altitude vegetation belts (Mercuri et al., 2012). In the Po Plain, for example, many archaeological sites dated to the Middle Bronze age show large amount of reworked pollen coupled with maxima of *Pinus*, together with *Abies*, *Fagus*, *Betula*, *Picea* and pollen grains at the bottom layer of the pollen diagram (Mercuri et al., 2006, 2014b).

In the Trench *Campi-S2*, the input from higher belts cannot be excluded but the component of 'mountain trees' is not so high to affect the interpretation of the pollen diagram (Fig. 5). The potential of alluvial sites towards reconstruction of vegetation history in lowlands settled by different cultures, from prehistoric to Medieval archaeological sites, has been demonstrated by Albert and Pokorný (2012) who studied Central European (Czech Republic) contexts. As we observe in the Po Plain, they find that the hydrological change influences pollen taphonomy in alluvial layers essentially leading to differential representation of saccatae pollen, buoyant on water surfaces in low-energy situations; *Pinus* pollen is responsible for the highest contribution of saccatae pollen to the deposits while



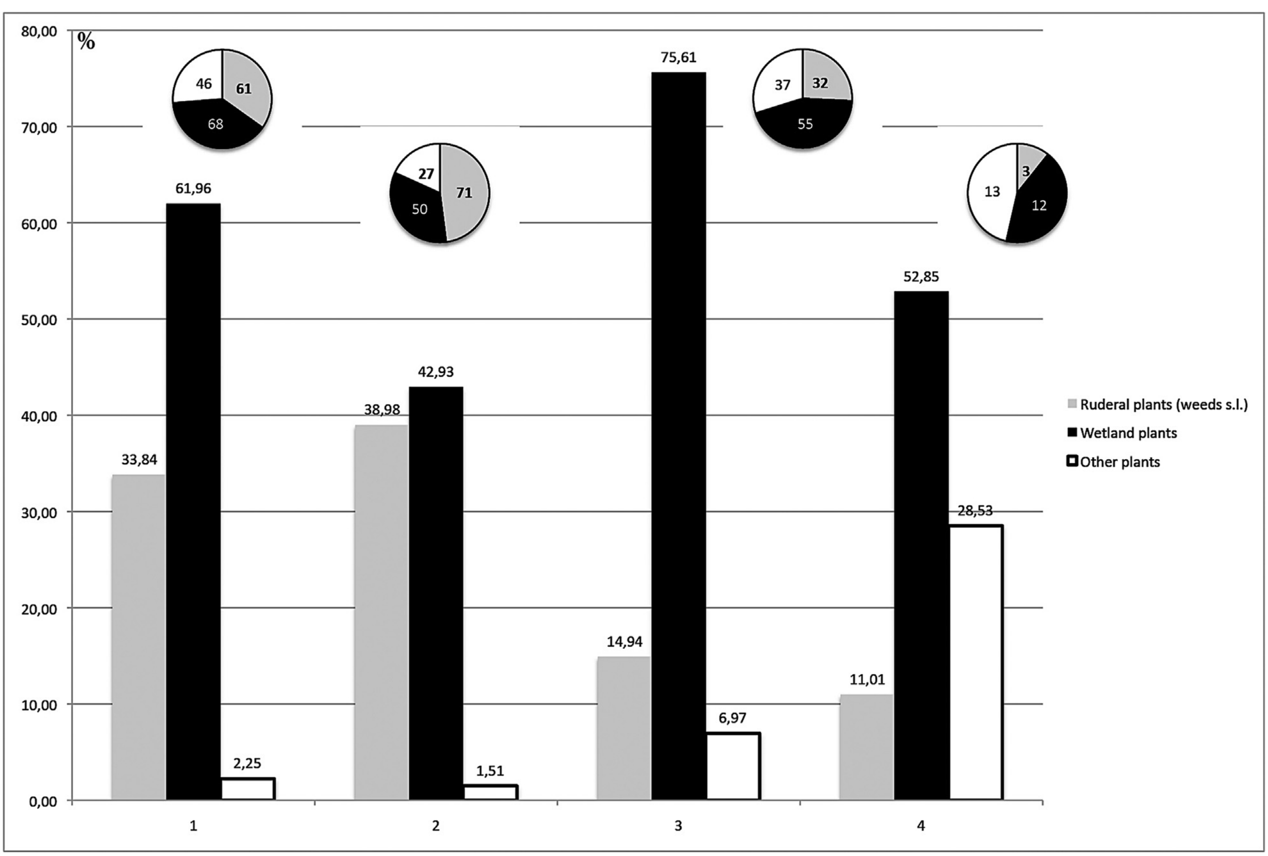


Fig. 4. Synthesised results of seed/fruit analyses from the four archaeological (MO-arch) sites. Histograms represent percentages of various sums; pie graphs report on the number of taxa per sum.

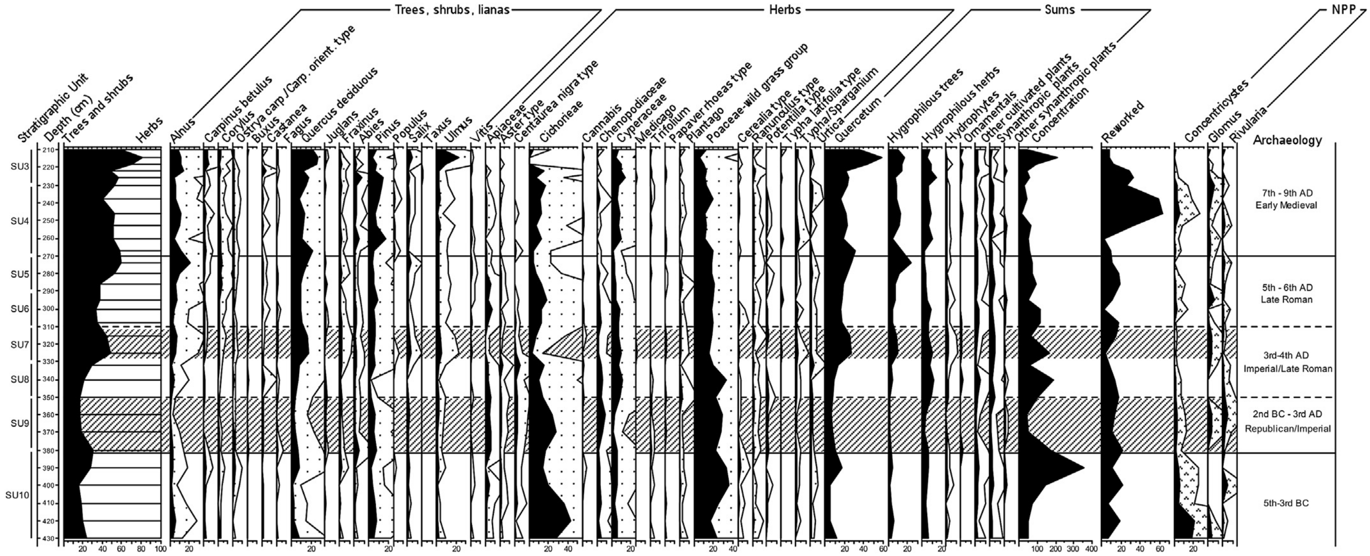


Fig. 5. Percentage pollen diagram of Trench *Campi-S2* (enhanced curves × 10). Taxa included in the sums are listed in Table 1; the grey screen mark the paleosols deposited during Roman times.

Abies pollen is significantly of local origin (Albert and Pokorný, 2012: p. 95).

In the five sites of Modena, the palaeoenvironmental reconstructions may be obtained from comparison and integration of data from the different sites. The plant taxa that were recurrent, sometimes dominant, in these on-site/off-site records represent both the plant cover and the species with cultural significance in the study area (Mercuri et al., 2014a).

Moreover, the good preservation of macro-remains, prevalently found waterlogged, and the types of archaeological contexts investigated allow us to reconstruct both the environment around the city and the food production and consumption at Roman times. Cultivated and synanthropic plants were abundant suggesting that the natural vegetation was shaped by agricultural and other human activities as early as the foundation of the town during the Roman Republic. Similar evidence was found in the town of Parma, founded by Romans as well, and located about 40 km far from Modena, along the *Via Aemilia* in Emilia Romagna (Bosi et al., 2011a).

Crops from fields and ornamentals from gardens characterise the urban-suburban contexts. Below, these features are reported by integrating pollen (Figs. 3 and 5) and seeds/fruits data (ESM Table), and by reporting firstly the general characteristics of the town and then the specific (local) features of each site.

4.1. Palaeoenvironmental inferences

Wetlands and freshwater environments were spread everywhere (Bosi et al., in press). Pollen and seeds/fruits point to the floristic richness of these habitats which include hygrophilous woods (*Alnus*, *Salix* and *Populus*), and herbaceous plants (*Alisma* type, *Alisma plantago-aquatica*, *Baldellia ranunculoides*, *Lemna*, *Nymphaea alba* type, *Callitriche*, *Carex*, *Cyperus*, *Schoenoplectus*, *Potamogeton*, *Ranunculus aquatilis* group and *R.* subgen. *Batrachium*, *Myriophyllum*, *Najas minor*, *Zannichellia palustris*, *Sparganium erectum*, *Typha/Sparganium*, etc.). Wetland plants represent more than 40% of the seeds/fruits spectra, with maximum 76% in MO-arch3 and minimum 43% in MO-arch2 (Fig. 4). The latter is in line with the context: this is in fact the *domus*, a site most influenced by human presence (see below). In the pollen spectra, the maximum was similarly observed in MO-arch3 (47% on average) and the minimum in MO-arch2 (8%). The wet habitats were also identified by several NPPs – Non Pollen Palynomorphs: *Ceratophyllum* leaf spinules, algae such as *Pediastrum*, *Tribonema* type, *Rivularia*, and spermatophores of copepods were observed in MO-arch1.

Most of the water was controlled through an efficient ducting system favouring cultivations in the area. This is known from historical sources on *Mutina* (Calzolari, 2008) and by some archaeological evidence (MO-arch3). However, this is also independently suggested by the fact that the archaeobotanical record point to a wide distribution of cereal fields in the area, and this means that the land was necessarily drained to promote crops:

i) Cerealia type is present in 47% of the pollen spectra (in 42% of MO-arch sites; in 73% of the Trench, and in 71% of Roman layers); pollen of cereals is generally not easily transported far from the plant source (e.g., Diot, 1992), and in our samples they are common, especially in Roman layers: this suggests that living plants are expected to grow in the vicinity of the record analysed; ii) a variety of commensal and weed herbs are recorded in the seeds/fruits record (e.g. *Agrostemma githago*, *Ajuga chamaepytis*, *Anagallis arvensis*, *Anthemis cotula*, *Bromus arvensis*, *B. secalinus*, *Digitaria sanguinalis*, *Fallopia convolvulus*, *Heliotropium europaeum*, *Lapsana communis*, *Sonchus*).

Besides the hygrophilous woods, mixed broadleaved oak woods were prevalent producing pollen of deciduous *Quercus*, *Acer campestris* type, *Corylus* and other Corylaceae (*Carpinus betulus* and *Ostrya carpinifolia/C. orientalis* type), *Fraxinus*, *Tilia* and *Ulmus*, and macroremains of *Corylus* and *Quercus*. The mean percentage of the tree pollen sum from the trench (40%), together with climbing lianas such as *Hedera*, *Humulus* and *Clematis*, suggest that a thin forest covered the plain. There are evidence that woodlands have been managed since the Middle Bronze Age in the surroundings of the town (see, for example, the terramare of Baggiovara and Casinalbo, Mercuri et al., 2014b). During the Roman Republic/Imperial phases this forest was rather sparse (24%). The comparison with the on-site values, though their variable data depends on human influence more than airborne or water pollen transport, suggests that the plant distribution was probably rather diversified, over time and space, corresponding to the various expansion phases of the town and to the consequent fragmentation of the anthropogenic habitat.

Interestingly, pollen grains of *Castanea* and *Abies*, with similar mean percentages, are almost ubiquitous: in fact, they are present

in the 87% and 79% of on-site samples, respectively, and in the 90% and 100% of off-site samples. These trees are currently distributed in the hills and in mountains, respectively. Long-distance transport of both pollen taxa may be assumed (Mercuri, 2014). Concordly, pollen evidence suggests that woodlands with chestnut and fir trees were largely distributed across the low slopes of the Apennines, and possibly some fringes grew near the plain. Both these plants were spread all long the peninsula during the Roman times (Di Pasquale et al., 2010, 2014; Sadori et al., 2010b; Mercuri et al., 2013). However, they had very different histories, partly influenced by human activities. Pollen of chestnut has been sparsely present in Italy since the Lateglacial, before starting to increase a few centuries before the Roman times, c. 3000 cal. years BP (Mercuri et al., 2002; Sadori et al., 2010b). The pollen diagram from the trench shows a certain increase of *Castanea* pollen during the Early Medieval age (Fig. 5). In Medieval times, in Italy, its pollen notably increased mirroring the development of the 'chestnut landscape' in the Po Plain around 1200–1300 AD (Mercuri et al., 2012). Charcoal analyses show that the spread of chestnut has been locally visible in northern Italy (for example, in the area of Lago di Como and in the Tuscan-Emilian Apennines) even before, in the 500–600 AD (Rottoli and Negri, 1998; Castiglioni et al., 2001).

Fir spread notably at the beginning of the mid-Holocene when it probably grew both as monospecific woods in the hills and was scattered across the plain, until at c. 5500 cal. BP; it then suffered by the fall in precipitation, and was further cleared before and during the Bronze Age (Mercuri et al., 2006, 2012; Vescovi et al., 2010). The data from Modena suggest that, though it largely remained confined to the mountains, fir was possibly also part of hilly woodlands, along with chestnut trees, in this area during Roman and Early Medieval times.

4.2. The features of the investigated sites (Fig. 3, ESM Table)

The Roman *Mutina* and its surroundings were characterised by different degrees and types of anthropisation, with spots of low to high impact in the diverse contexts. Agrarian landscapes and the presence of some ornamental or 'possibly ornamental' plants, such as *Buxus*, *Cupressus sempervirens*, *Platanus*, and also *Betula*, *Celtis* and *Taxus* (see below), were the main traits of the suburban and urban contexts, respectively, where also the semi-natural lands were all permeated by human influence.

4.2.1. MO-arch1: 5th BC–6th century AD; the wetland at the edge of the town

The archaeobotanical record is characterised by hygrophilous trees and varied micro- and macroremains from pond and marsh plants. Pollen of Cichorieae, along with *Trifolium* type and *Medicago*, testify that the area was used for animal grazing (Mercuri et al., 2010, 2012). Disturbed habitats are indicated by a rich set of ruderal plants (e.g. *Urtica dioica* type, *Plantago*, *Papaver rhoeas* type and c. 60 sf taxa; ESM Table). Fields were probably not cultivated locally, as the Cerealia type percentage (0.9%) is insignificant. Only samples of seeds/fruits from the 1st–2nd century AD contain varied cultivated plants, including cereals (*Secale cereale* and *Hordeum vulgare*), fruits (*Cucumis melo*, *Ficus carica*, *Juglans regia*, *Olea europaea*, *Pinus pinea*, *Prunus avium*, *Prunus persica*, *Vitis vinifera* and the exotic date from *Phoenix dactylifera*), and vegetables (*Lagenaria siceraria*).

4.2.2. MO-arch2: 3rd BC–3rd century AD; the domus at the centre of the town

This important building representing the true centre of the town, preserved signs of human-influenced habitats more than the other sites. In the archaeobotanical record, these signs are: i) the huge amount of cereals as pollen (4%) and charred seeds/fruits (75 records), in the *pre-domus* and *domus* phases; ii) cultivated pulses (e.g. *Lens culinaris* and *Vicia faba*) and vegetable/aromatic plants (e.g. *Atriplex hortensis*, *Anethum* type, *Apium graveolens*, *Origanum vulgare*, *Satureja hortensis*); iii) ornamental plants represented by their pollen and/or the sf of *Acanthus*, *Cupressus sempervirens*, *Myrtus*, *Platanus* and *Taxus*. In line with the archaeological data, the abandonment of the site in the 2nd–3rd century AD was also evident from the macroremains record, i.e. the disappearance of vegetables and ornamental plants, and a general decrease of taxa in these samples (ESM Table).

4.2.3. MO-arch3: 2nd BC–9th/10th century AD; the aqueduct and wetlands far from the town

Species of the *Lemnetea* and *Potametea* associations are significantly frequent at the site in the phase A (aqueduct; Table 1; Bosi et al., in press). Once the aqueduct and channel were abandoned, and the alluvial layers covered the structures, an alder wood was established as the first step of a return to a mature woodland. Possibly, *Abies* (found as pollen and one needle) grew in this place. Local anthropisation is not evident (cereal pollen is insignificant – 0.1%, and synanthropics are low – 2%). The rapid expansion of wet environments and the development of hygrophilous woods are marked by pollen and macroremains from pond and stream habitats. High local biodiversity is indicated by floating/submerged plants (e.g. *Ceratophyllum*, *Lemna*, *Myriophyllum*, *Potamogeton*, *Ranuculus* subg. *Batrachium*), and emergent plants (e.g. *Alisma plantago-aquatica*, *Carex*, *Cyperus*, *Lycopus europaeus*, *Mentha aquatica*, *Sparganium emersum*, *Typha angustifolia* type) (*sensu* Cronk and Fennessy, 2001). A number of species that not grow in the Modena's territory today and are, therefore, locally extinct are identified: *Baldellia ranunculoides*, *Cladium mariscus*, *Cicuta virosa*, *Cyperus flavescens*, *Potamogeton perfoliatus* (Bosi et al., in press).

4.2.4. MO-arch4: 1st–10th century AD; a semi-natural area at the periphery of the town

An open environment between the town and woodlands was characterised by low tree cover (26% on average; dominated by *Alnus* in sample 4: Fig. 5). The humid soils were probably subjected to frequent increases/decreases in water levels content (*Concentricystes* and *Rivularia*). Wet grassland with *Cyperus longus* and other Cyperaceae, *Ranunculus sceleratus*, *Potentilla reptans* and *Solanum dulcamara* were widespread in the earliest phase, while dry grassland with Cichorieae were higher in the more recent layers. These herbs, with *Centaurea nigra* type and fodder plants (*Medicago*, *Onobrychis* type, *Trifolium* type) suggest that the area was used for grazing. Signs of cultivations (*Vitis*, *Cannabis*, Cerealia type) were few, yet human presence was evident from anthropogenic indicators such as *Artemisia* and *Plantago*. This type of environmental context remained fairly widespread around the towns of the Po Plain up to the beginning of the last century.

5. Trench Campi-S2

Oak woodlands and hygrophilous woodlands, with some transitional associations with elm, were the main elements of the forest cover. As discussed above, water transport was responsible of the inclusion of some pollen from long distance in alluvial layers. Considering the ubiquity of some pollen grains, and the presence also in paleosols, it is also possible that pines (*Pinus sylvestris* type) together with *Abies* and *Fagus* lived at a lower altitude than today.

The arboreal pollen trend suggests that woodlands were less extended in the Roman Republic and Imperial phases, and became ever more widespread in the Late Roman and Early Medieval phases (Fig. 5). Actually the geomorphological and

lithostratigraphical data, obtained from many contexts of Modena, suggest that a large forest clearance occurred in lowlands and hills during the late Republican/Imperial phases corresponding to a significant demographic increase, while a partial woodland regeneration had occurred corresponding to a demographic decrease since the beginning of the Late Roman phase (Cremonini et al., 2013: p. 174).

Wet habitats with *Typha* and Cyperaceae – such as river margins, or ponds and streams – hosted a number of floating/submerged plants such as *Callitriche*, *Lemna*, *Potamogeton*, and algae. The wetland plants are well represented in the spectra of the trench and of the archaeological sites from both the centre of the town (MO-arch2), and the surroundings (MO-arch2 and MO-arch3): this confirms the wide distribution of these habitats in the past as in the present times with fairly the same prevalent genera (e.g. Buldrini et al., 2013; Gomarasca et al., 2013). Although archaeological data testify that extended land reclamation was performed (Cremonini et al., 2013), wetlands continued to be common even during the Roman phases in the area.

Grasslands are represented by Poaceae-wild grass group and Cichorieae that, together with the *Centaurea nigra* type and *Trifolium* type may be grazing indicators. These environments are prevalent in Roman phases and fairly gradually decreased in Early Medieval phases, towards the top of the diagram (Fig. 5). An alternation of wet and dry pastures is suggested by observing the Cichorieae–Cyperaceae trend of the trench diagram: this might have had local (different localisation in/around the town), seasonal (summer/dry and spring/wet phases), chronological and climatic causes. In keeping with the latter hypothesis, a change was observed in the pollen spectra from MO-arch4, where a wet habitat/grassland with Cyperaceae (samples 6, 7 in Fig. 3) was followed by dry grassland with high Cichorieae (sample 5) in the 4th–5th century AD. These data are quite fragmentary. However, written sources emphasised that during the Climate Optimum period (100 BC–200 AD) there was moisture predominantly in the form of the flooding of the River Tiber in Rome (and see Benvenuti et al., 2006, for the River Arno); then the climate became instable with oscillations, such as the cooler and drier climate of the 3rd century and shift to warming in the 4th century (McCormick et al., 2012).

Both cultivated woody plants (*Castanea*, *Juglans* and *Vitis*) and cereals (*Hordeum* group, *Avena/Triticum* group), along with the anthropophyte *Papaver rhoeas* type, were found: these pollen grains are evidence that living trees and fields were widespread in the area.

The mean values of cereals suggests that cereal fields were more widespread in the Roman (0.8%) than in the Early Medieval (0.3%) age; they cannot be regarded as clear evidence that fields were cultivated in that place. Combining these data with those from the MO-arch3 site, it may be argued that cereal fields were not cultivated at about 1.8–2 km far south of *Mutina*. Besides the grazing indicators, cultivated plants and weeds, other synanthropic plants are well represented in the spectra (e.g. *Artemisia*, *Plantago*, *Urtica dioica* type).

Cannabis is very common – the 0.4% on average was found in 45% of the samples – and its presence may reasonably point to hemp cultivation in the area. In fact, it is known that the Romans imported fibres for ropes and sails from Gaul during the 3rd century BC, and then cultivated and processed hemp in central and northern Italy (Mercuri et al., 2002). On the Po Plain, this agricultural activity has continued as part of a long tradition up until the past century.

6. Conclusions

This research shows the habitat diversity of a Roman town located in Po Plain, in Northern Italy.

The integrated study of micro- and macro-remains, the interdisciplinary archaeological and botanical approach, and the comparison on-site/off-site records allow the reconstruction of an urban environment of the past. Like other towns, Modena – not only 'an urban site' – is an invaluable source of evidence from palaeoenvironmental inferences through plant remains. Close to rivers and doubtless with a high water-table, it has preserved a huge quantity of remains. Wetlands were more extended in the past than in the current times and they have probably always been the main feature of the landscapes surrounding towns on the Po Plain. Water availability was a continuative and precious resource for agriculture. On the other hand, it was an ongoing challenge for humans, who had to face floodings and the rapid re-spreading of wetlands when farmlands were abandoned (as in MO-arch3).

In the dynamics of natural vs. anthropogenic environments, combining data from the different points of investigation provided us with a patchy landscape during the Roman period:

- the area was characterised by low forest cover; the management of oak woodlands, that was visible in the area since the Middle Bronze age, continued during this period; the oak-hornbeam forests were prevalent and they actually represent a zonal – virtually extinct – vegetation in the Po valley in modern times (Košir et al., 2013);
- woodlands of mixed conifer and broadleaved trees grew prevalently near/towards the hills, while hygrophilous woods were also extended throughout the plain;
- the plain was largely occupied by freshwater habitats, with ponds, streams, rivers and artificial (cleaned) channels; wetlands generally expanded in abandoned or less frequented sites;
- the plant landscape was shaped by human activities such as wet or dry pasturelands and cereal fields outside the town walls, while ruderal habitats spread across human-disturbed environments.

The main traits of the modern urban environment, with ornamental plants and fragmentation of habitats was already present in the Roman times, while a return of semi-natural environments with hygrophilous woodlands at the edges of the town was evident during the Early Medieval age in this part of the Po Plain.

Appendix A. Supplementary data

Supplementary data related to this article can be found at http://dx.doi.org/10.1016/j.jas.2014.09.020.

References

Albert, B.M., Pokorný, P., 2012. Pollen taphonomy and hydrology at Vranský potok versus Zahájí Alluvial pollen sites: methodological implications for cultural landscape reconstruction in the Peruc Sandstone Area, Czech Republic. Interdiscip. Archaeol. 3 (1), 85–101.

Alessandrini, A., Delfini, L., Ferrari, P., Fiandri, F., Gualmini, M., Lodesani, U., Santini, C., 2010. Flora del Modenese. Artestampa, Modena.

Alonso Martinez, N., 2005. Agriculture and food from the Roman to the Islamic Period in the North-East of the Iberian peninsula: archaeobotanical studies in the city of Lleida (Catalonia, Spain). Veg. Hist. Archaeobot. 14, 341–361.

Anghinetti, C., Bosi, G., Labate, D., Marchesini, M., 2011. Modena, Viale Amendola. Acquedotto e bosco di età romana. In: Atti e Memorie Deputazione di Storia Patria per le Antiche Province Modenesi (2009), vol. XXXIII. Aedes Muratoriana, Modena, pp. 440–443.

Bandini Mazzanti, M., Mercuri, A.M., Bosi, G., Marchesini, M., Accorsi, C.A., 2001. The archaeobotanical archive: plants used by man (which, were, how, when?). What fruits did Romans eat in Emilia Romagna (Northern Italy)? Some responses from seeds and fruits. In: Guarino, A. (Ed.), Science and Technology for

the Safeguard of Cultural Heritage in the Mediterranean Basin. CNR, Alcalà, pp. 318–324.

Bandini Mazzanti, M., Bosi, G., Mercuri, A.M., Accorsi, C.A., Guarnieri, C., 2005. Plant use in a city in Northern Italy during the Late Medieval and Reinaissance periods: results of the archaeobotanical investigation of "The Mirror Pit" (14th–15th century A.D.) in Ferrara. Veg. Hist. Archaeobot. 14 (4), 442–452.

Benassi, F., Guandalini, F., 2011. Modena, via Università, Ex Cinema Capitol. *Domus* di età romana. In: Atti e Memorie Deputazione di Storia Patria per le Antiche Provincie Modenesi (2009), vol. XXXIII. Aedes Muratoriana, Modena, pp. 430–431.

Beneš, J., Kaštovský, J., Kočárová, R., Kočár, P., Kubečková, K., Pokomý, P., Starec, P., 2002. Archaeobotany of the Old Prague Town defence system, Czech Republic: archaeology, macro-remains, pollen, and diatoms. Veg. Hist. Archaeobot. 11, 107–119.

Beneš, J., Čulíková, V., Kosňovská, J., Frolík, J., Matiášek, J., 2012. New plants at Prague Castle and Hradčany in the Early Modern Period: a history of selected species. Interdiscip. Archaeol. 3 (1), 103–114.

Benvenuti, M., Mariotti Lippi, M., Pallecchi, P., Sagri, M., 2006. Late-Holocene catastrophic floods in the terminal Arno River (Pisa, Central Italy) from the story of a Roman riverine harbour. Holocene 16 (6), 863–876.

Berggren, G., 1969. Atlas of Seeds. Part 2. Cyperaceae. Swedish Museum of Natural History. Stockholm.

Berggren, G., 1981. Atlas of Seeds. Part 3. Salicaceae–Cruciferae. Swedish Museum of Natural History. Stockholm.

Beug, H.J., 1964. Untersuchungen zur spat- und postglazialen Vegetationsgeschichte im Gardaseegebiet unter besonderer Berücksichtigung der mediterranen Arten. Flora 154, 401–444.

Bosi, G., Mercuri, A.M., Guarnieri, C., Bandini Mazzanti, M., 2009. Luxury food and ornamental plants at the 15th century A.D. Renaissance court of the Este family (Ferrara, northern Italy). Veg. Hist. Archaeobot. 18 (5), 389–402.

Bosi, G., Bandini Mazzanti, M., Florenzano, A., Massamba N'siala, I., Pederzoli, A., Rinaldi, R., Torri, P., Mercuri, A.M., 2011a. Seeds/fruits, pollen and parasite remains as evidence of site function: Piazza Garibaldi – Parma (N Italy) in Roman and Mediaeval times. J. Archaeol. Sci. 38, 1621–1633.

Bosi, G., Rinaldi, R., Bandini Mazzanti, M., 2011b. Flax and weld: archaeobotanical records from *Mutina* (Emilia Romagna, Northern Italy), dated to the Imperial Age, first half 1st century A.D. Veg. Hist. Archaeobot. 20 (6), 543–548.

Bosi, G., Benatti, A., Rinaldi, R., Dallai, D., Santini, C., Tomaselli, M., Bandini Mazzanti, M. The memory of water: archaeobotanical evidences from wetland plants of the past in the city of Modena. Plant Biosyst. in press.

Bronk Ramsey, C., 2005. OxCal v.3.10. http://www.rlaha.ox.ac.uk/orau/calibration.html.

Buldrini, F., Dallai, D., Torri, P., 2013. Can palynology contribute to plant diversity conservation activities? the wetland plants in southern Po Plain as a case study. Ann. Bot. 3, 245–254.

Calzolari, M., 2008. Citta dell'*Æmilia: Mutina*. Le fonti letterarie di Modena romana. G.s.B.M, Modena.

Cappers, R.T.J., Bekker, R.M., Jans, J.E.A., 2006. Digitale Zadenatlas van Nederland. Barkhuis Publishing & Groningen University Library, Groningen.

Castaldini, D., Cardarelli, A., Cattani, M., Panizza, M., Piacentini, D., 2007. Geoarchaeological Aspects of the Modena Plain (Northern Italy). Physio-Géo 1. http://dx.doi.org/10.4000/physio-geo.1048. http://physio-geo.revues.org/1048.

Castiglioni, E., Cottini, M., Rottoli, M., 2001. I resti archeobotanici. In: Brogiolo, G.P., Castelletti, L. (Eds.), Archeologia a Monte Barro, pp. 223–247. II – Gli scavi 1990-97 e le ricerche al S. Martino di Lecco. Consorzio Parco Monte Barro, Museo Archeologico "P. Giovio" Como, Lecco.

Coletti, F., Celant, A., Pensabene, P., 2006. Ricerche archeologiche e paleoambientali sul Palatino tra l'età arcaica e la tardoantichità – primi risultati. In: D'Amico, C. (Ed.), Atti Convegno di Caserta dell'Associazione Nazionale di Archeometria. A.I.Ar. Pàtron Editore, Bologna, pp. 557–564.

Cremonini, S., Labate, D., Curina, R., 2013. The late-antiquity environmental crisis in Emilia region (Po river plain, Northern Italy): geoarchaeological evidence and paleoclimatic considerations. Quat. Int. 316, 162–178.

Cronk, J.K., Fennessy, M.S., 2001. Wetland Plants. Biology and Ecology. CRC Press, USA.

David, J.M., 2002. La Romanizzazione dell'Italia. Laterza, Bari.

Danin, A., Buldrini, F., Bandini Mazzanti, M., Bosi, G., 2014. The history of the *Portulaca oleracea* aggregate in the Emilia-Romagna Po Plain (Italy) from the Roman Age to the present. Plant Biosyst. 148 (4), 622–634.

Diot, M.F., 1992. Études palynologiques de blés sauvages et domestiques issus de cultures expérimentales. In: Anderson, P.C. (Ed.), Préhistoire de l'agriculture: nouvelles approches expérimentales et ethnographiques. Monographie du CRA 6. CNRS, Périgueux.

Di Pasquale, G., Allevato, E., Russo Ermolli, E., Lubritto, C., Yoneda, M., Takeuchi, K., Kano, Y., De Simone, G.F., 2010. Reworking the idea of chestnut (*Castanea sativa* Mill.) cultivation in Roman times: new data from ancient Campania. Plant Biosyst. 144, 901–909.

Di Pasquale, G., Allevato, E., Cocchiararo, A., Moser, D., Pacciarelli, M., Saracino, A., 2014. Late Holocene persistence of *Abies alba* in low-mid altitude deciduous forests of central and southern Italy: new perspectives from charcoal data. J. Veg. Sci. 25 (5), 1299–1310. http://dx.doi.org/10.1111/jvs.12196.

Faegri, K., Iversen, J., 1989. Textbook of Pollen Analysis, fourth ed. Wiley, Chichester.

Florenzano, A., Mercuri, A.M., Pederzoli, A., Torri, P., Bosi, G., Olmi, L., Rinaldi, R., Bandini Mazzanti, M., 2012. The significance of intestinal parasite remains in pollen samples from Mediaeval pits in the Piazza Garibaldi of Parma, Emilia Romagna, Northern Italy. Geoarchaeology 27, 34–47.

Gomarasca, S., Cicatelli, A., Maggioni, L.A., Castiglione, S., 2013. The use of *Callitriche* for water quality determination can be misleading: an example from the Po Valley in Northern Italy. Plant Biosyst. 147, 459–471.

Greig, J., 1996. Archaeobotanical and historical records compared – a new look at the of taphonomy of edible and other useful plants from the 11th to the 18th centuries A.D. Circaea 12 (2), 211–247.

Grenfell, H.R., 1995. Probable fossil zygnematacean algal spore genera. Rev. Palaeobot. Palynol. 84, 1–220.

Grimm, E.C., 2004. TILIA and TGView. Illinois State Museum, Springfield, IL.

Karg, S. (Ed.), 2007. Medieval Food Traditions in Northern Europe. PNM, Copenhagen.

Košir, P., Casavecchia, S., Čarni, A., Škvorc, Ž., Zivkovic, L., Biondi, E., 2013. Ecological and phytogeographical differentiation of oak-hornbeam forests in southeastern Europe. Plant Biosyst. 147 (1), 84–98.

Labate, D., 2013. Datazioni radiocarboniche, dendrocronologiche e archeologiche delle alluvioni di Modena e del suburbio. In: Atti e Memorie Deputazione di Storia Patria per le Antiche Provincie Modenesi (2011), vol. XXXV. Aedes Muratoriana, Modena, pp. 291–297.

Labate, D., Librenti, M., Pellegrini, S., Pulini, I. (Eds.), 2010. Parco Novi Sad. Archeologia di uno spazio urbano (catalogo della mostra 2010-2011). Comune di Modena, Museo Civico Archeologico Etnologico, Modena.

Librenti, M., 2013. Modena, Via Campi, nuova sede universitaria. Stratificazione dall'età romana all'età contemporanea. In: Atti e Memorie Deputazione di Storia Patria per le Antiche Provincie Modenesi (2009), vol. XXXV. Aedes Muratoriana, Modena, p. 307.

Lugli, S., Fontana, D., Giordani, N., Labate, D., Sacco, D., 2002. Stratigrafia e composizione dei sedimenti sabbiosi del sottosuolo di Modena: implicazioni nell'alluvionamento della città romana. Risultati preliminari. In: Atti Secondo Congresso Nazionale Associazione Italiana di Archeometria AIAr, pp. 341–351. Bologna.

Malnati, L., 1988. La città romana: Mutina. In: Cardarelli, A. (Ed.), Modena dalle origini all'anno Mille. Studi di archeologia e storia. I. Panini, Modena, pp. 307–337.

Mariotti Lippi, M., Bellini, C., Mori Secci, M., Gonnelli, T., Pallecchi, P., 2013. Archaeobotany in Florence (Italy): landscape and urban development from the late Roman to the Middle Ages. Plant Biosyst. http://dx.doi.org/10.1080/11263504.2013.822433.

Martinelli, N., Pignatelli, O., 2013. Modena, Viale Amendola. Indagini dendrocronologiche e radiocarboniche. In: Atti e Memorie Deputazione di Storia Patria per le Antiche Provincie Modenesi, vol. XXXV. Aedes Muratoriana, Modena, pp. 363–365.

McCormick, M., Büntgen, U., Cane, M.A., Cook, E.R., Harper, K., Huybers, P., Litt, T., Manning, S.W., Mayewski, P.A., More, A.F.M., Nicolussi, K., Tegel, W., 2012. Climate change during and after the Roman Empire: reconstructing the past from scientific and historical evidence. J. Interdiscipl. Hist. 43, 169–220.

Mercuri, A.M., 2014. Applied palynology as a trans-disciplinary science: the contribution of aerobiology data to forensic and palaeoenvironmental issues. Aerobiologia (in press).

Mercuri, A.M., Accorsi, C.A., Bandini Mazzanti, M., 2002. The long history of *Cannabis* and its cultivation by the Romans in central Italy, shown by pollen records from Lago Albano and Lago di Nemi. Veg. Hist. Archaeobot. 11 (4), 263–276.

Mercuri, A.M., Accorsi, C.A., Bandini Mazzanti, M., Bosi, G., Cardarelli, A., Labate, D., Trevisan Grandi, G., 2006. Economy and environment of Bronze Age settlements – Terramaras – in the Po Plain (Northern Italy): first results of the archaeobotanical research at the Terramara di Montale. Veg. Hist. Archaeobot. 16, 43–60.

Mercuri, A.M., Florenzano, A., Massamba N'siala, I., Olmi, L., Roubis, D., Sogliani, F., 2010. Pollen from archaeological layers and cultural landscape reconstruction: case studies from the Bradano Valley (Basilicata, southern Italy). Plant Biosyst. 144 (4), 888–901.

Mercuri, A.M., Bandini Mazzanti, M., Torri, P., Vigliotti, L., Bosi, G., Florenzano, A., Olmi, L., Massamba N'siala, I., 2012. A marine/terrestrial integration for mid-late Holocene vegetation history and the development of the cultural landscape in the Po valley as a result of human impact and climate change. Veg. Hist. Archaeobot. 21 (4–5), 353–372.

Mercuri, A.M., Mazzanti Bandini, M., Florenzano, A., Montecchi, M.C., Rattighieri, E., 2013. *Olea*, *Juglans* and *Castanea*: the OJC group as pollen evidence of the development of human-induced environments in the Italian peninsula. Quatern. Int. 303, 24–42.

Mercuri, A.M., Allevato, E., Arobba, D., Bandini Mazzanti, M., Bosi, G., Caramiello, R., Castiglioni, E., Carra, M.L., Celant, A., Costantini, L., Di Pasquale, G., Fiorentino, G., Florenzano, A., Guido, M., Marchesini, M., Mariotti Lippi, M., Marvelli, S., Miola, A., Montanari, C., Nisbet, R., Peña Chocarro, L., Perego, R., Ravazzi, C., Rottoli, M., Sadori, L., Ucchesu, M., Rinaldi, R., 2014a. Pollen and plant remains from Holocene archaeological sites: a dataset for the understanding of the biocultural diversity of the Italian landscape. Rev. Palaeobot. Palynol. http://dx.doi.org/10.1016/j.revpalbo.2014.05.010.

Mercuri, A.M., Montecchi, M.C., Pellacani, G., Florenzano, A., Rattighieri, E., Cardarelli, A., 2014b. Environment, human impact and the role of trees in the Po plain at the Middle and Recent Bronze age: pollen evidence from the local influence of the terramare of Baggiovara and Casinalbo. Rev. Palaeobot. Palynol. http://dx.doi.org/10.1016/j.revpalbo.2014.08.009.

Moore, P.D., Webb, J.A., Collins, M.E., 1991. Pollen Analysis, II ediz. Blackwell Sc. Publ., Oxford.
Murphy, C., Thompson, G., Fuller, D.Q., 2013. Roman food refuse: urban archaeobotany in *Pompeii*, *Regio* VI, *Insula* 1. Veg. Hist. Archaeobot. 22 (5), 409–419.
Pignatti, S., 1982. Flora d'Italia, I, II, III. Edagricole, Bologna.
Reille, M., 1992. Pollen et spores d'Europe et d'Afrique du Nord. Laboratoire de botanique historique et palinologie. URA CNRS 1152, Marseille.
Rinaldi, R., 2010. Archeobotanica del Periodo Romano nell'area di Modena nel quadro delle conoscenze archeobotaniche nell'ambito emiliano-romagnolo. Doctoral thesis. University of Modena and Reggio Emilia.
Rinaldi, R., Bandini Mazzanti, M., Bosi, G., 2013. Archaeobotany in the urban sites: the case of *Mutina*. Ann. Bot. 3, 217–230.
Rottoli, M., Negri, S., 1998. I resti vegetali carbonizzati. In: Giannichedda, E. (Ed.), Filattiera-Sorano: l'insediamento di età romana e tardo antica – Scavi 1986–1995, pp. 198–212. Firenze.
Sander, J., Wardell-Johnson, G., 2012. Defining and characterizing high-rainfall Mediterranean climates. Plant Biosyst. 146, 451–460.
Sadori, L., Giardini, M., Giraudi, C., Mazzini, I., 2010a. The plant landscape of the Imperial harbour of Rome. J. Archaeol. Sci. 37, 3294–3305.
Sadori, L., Mercuri, A.M., Mariotti Lippi, M., 2010b. Reconstructing past cultural landscape and human impact using pollen and plant macroremains. Plant Biosyst. 144, 940–951.
Sadori, L., Giardini, M., Celant, A., 2011. Gli studi paleobotanici. Le conoscenze botaniche del Lazio dal 1950 al 2010: stato dell'arte. Inf. Bot. Ital. 43 (1), 131–134.
Święta-Musznicka, J., Latałowa, M., Badura, M., Gołembnik, A., 2013. Combined pollen and macrofossil data as a source for reconstructing mosaic patterns of the early medieval urban habitats: a case study from Gdańsk, N. Poland. J. Archaeol. Sci. 40, 637–648.
van Geel, B., Buurman, J., Brinkkemper, O., Schelvis, J., Aptroot, A., van Reenen, G., Hakbijl, T., 2003. Environmental reconstruction of a Roman Period settlement site in Uitgeest (The Netherlands), with special reference to coprophilous fungi. J. Archaeol. Sci. 30, 873–883.
Vescovi, E., Kaltenrieder, P., Tinner, W., 2010. Late-Glacial and Holocene vegetation history of Pavullo nel Frignano (Northern Apennines, Italy). Rev. Palaeobot. Palynol. 160, 32–45.